WHAT IS CLAIMED IS:

1. A method for evacuating and detecting leaks in a sealed internal reference chamber of a solid electrolyte oxygen sensor, having an internal electrode and an external electrode, said method comprising:

a. applying a first direct current (DC) pumping current to the internal and external electrodes to evacuate the reference chamber while measuring a sensor voltage and while measuring an elapsed time from the application of said DC pumping current;

b. comparing the measured sensor voltage and the measured elapsed time to a predetermined sensor voltage limit and a first predetermined elapse time limit respectively to ascertain the presence of a leak in said reference chamber;

c. progressively reducing the DC pumping current applied to the sensor electrodes to continue the evacuation of the reference chamber, and

d. while reducing the current, comparing the reduced DC pumping current to a predetermined current limit and comparing the elapsed time to a second predetermined time limit to detect a leakage in the chamber.

2. The method of claim 1 further comprising initializing a pump current magnitude control variable i_{pump}, via an intermediate calculation variable i_{new}, to a first maximum value i_{FS}.

3. The method of claim 1, wherein the method further comprises a sensor emptying loop comprising:

determining whether a DC pump voltage across the electrodes is greater than a predetermined pump voltage limit to determine whether the chamber is evacuated, and

determining whether a first elapsed time limit has occurred during the emptying loop and before the chamber has been fully evacuated as indicated by said DC pump voltage being greater than said predetermined pump voltage limit.

4. The method of claim 3, wherein the determination of sensor evacuation further comprises comparing the DC pump voltage value SmV to the predetermined pump voltage limit EmV wherein EmV corresponds to a pump voltage occurring when the chamber is substantially evacuated.

5. The method of claim 3, wherein the determination of an elapsed time limit further comprises a comparison of the elapsed time from the first application of the DC pumping current to a first preprogrammed time limit value t_1 such that an elapsed time greater than t_1 indicates a leak in the chamber.

6. The method of claim 1 further comprising a pumping current reduction loop comprising:

determining whether a minimum pumping current has been applied as the pumping current is reduced, and

if the minimum current has not yet been applied, determining whether the elapsed time exceeds a time limit for reducing the pumping current.

7. The method of claim 6 wherein the reduction of the pumping current further comprises:

setting a pump current magnitude control variable i_{pump}, to a value held in an intermediate calculation variable i_{new}, with i_{new} set to a preprogrammed maximum value i_{FS} in a first iteration and a conditionally reduced value of each preceding i_{pump} value for further iterations during the elapsed time.

8. The method of claim 6, wherein the determination of the minimum pumping current further comprises:

comparing i_{pump} the pumping current being applied to a preprogrammed minimum pumping current limit i_{min}, and

if the applied pumping current is less than the predetermined minimum current, determining the chamber to be leak free.

9. The method of claim 6 wherein the determination of the elapsed time further comprises comparing an elapsed time from the first application of the DC pumping current to a second preprogrammed time limit value t_2, such that an elapsed time greater t_2 indicates a leak in the chamber.

10. The method of claim 7 wherein a subsequent pumping current i_{new} is determined as a function of a preceding pump current i_{pump} as follows:

$$i_{new} = i_{pump} \times k_1$$

where:

$$k_1 = 2 - \left(\frac{SmV}{EmV} \right)$$

wherein SmV is a current DC pump voltage and EmV corresponds to a pump voltage occurring when the chamber is substantially evacuated.

11. The method of claim 1 wherein the steps of the method repeat until the sensor reference chamber is determined to be either evacuated and leak free or to leak.

12. A method for pumping a sealed internal reference chamber of a solid electrolyte oxygen sensor, having an internal electrode and an external electrode, during a dynamically controlled, null balancing, calibration process, said method comprising:

a. initializing a set of pumping current pulse parameters controlling pulse ON time, post pulse RELAXATION time and pulse magnitude;

b. applying a pulsed pumping current based on said set of pulse parameters to the internal and external electrodes, wherein the application of current transitions the chamber from a substantially evacuated state to a substantially null or balanced oxygen partial pressure state with respect to an applied external calibration gaseous environment;

c. periodically comparing the Nernst voltage of the sensor to a predetermined limit to determine whether the chamber is at a null or balanced state;

d. comparing an elapsed time from the application of said pulsed pumping current to a third predetermined time limit to determine if the sensor has failed, and

e. progressively reducing at least one of the magnitude, ON time and RELAXATION time of said pumping current pulses to slow the transition as the chamber approaches the null or balanced oxygen partial pressure state.

13. The method of claim 12 further comprising initializing a pump current pulse ON time control variable OT_{pump} to a first maximum preprogrammed value OT_{SP}.

14. The method of claim 12 further comprising initializing a pump current pulse RELAXATION time control variable RT_{pump} to a first maximum preprogrammed value RT_{SP}.

15. The method of claim 12 further comprising initializing a pump magnitude control variable i_{pump} via an intermediate calculation variable i_{new} to a first maximum value i_{FS} according to:

$$i_{new} = i_{FS} \times k_2$$

where:

$$k_2 = \left(\frac{aPP_{CAL}}{sPP_{AIR}} \right)^{\left(\frac{1}{sfp}\right)}$$

where aPP_{CAL} represents an oxygen partial pressure of a calibration gas applied to an external environment of the sensor, sPP_{AIR} represents an oxygen partial pressure of air at a standard barometric pressure value, and where an output result of expression k_2 is maximally limited to a value of 1 in a case where the value of aPP_{CAL} is greater than a value of sPP_{AIR}.

16. The method of claim 12, wherein the method further comprises a sensor nulling loop comprising:

measuring the Nernst voltage across the electrodes;

based on said voltage, determining whether the sensor is at the null state;

if the sensor is not at the null state, determining whether an elapsed time during the nulling loop exceeds a third preprogrammed time limit, and

if the elapsed time does not exceed the time limit, dynamically reducing the pumping current pulse parameters and repeating the nulling loop.

17. The method of claim 16 wherein the sensor null state determination further comprises comparing a sensor absolute Nernst voltage value AnV to a preprogrammed target value Null Window such that a value of AnV less than the Null Window value indicates the sensor is at the null or balanced state.

18. The method of claim 16, wherein the elapsed time limit determination further comprises:

comparing the measured elapsed time from a first application of the pumping current in a first iteration of said nulling loop to the preprogrammed time limit value t_3, and

determining the sensor to have failed if the elapsed time is greater than t_3.

19. The method of claim 16 further comprising a dynamic reduction process that comprises:

comparing a sensor Nernst voltage absolute value AnV to a preprogrammed trip value mVTrip, such that an AnV value less than mVTrip triggers a set of pump pulse dynamic reduction expressions in an alternate sensor nulling loop and

an AnV value greater than mVTrip triggers a repetition of the sensor nulling loop using the first initialized pump pulse parameters.

20. The method of claim 19 wherein the alternate sensor nulling loop further comprises a pump pulse magnitude reduction expression, a pump pulse ON time reduction expression and a pump pulse RELAXATION time reduction expression.

21. The method of claim 20 further comprising reducing an instantaneous pump pulse current magnitude variable i_{pump} from an initial conditioned value held in the intermediate calculation variable i_{new} to a next value according to:

$$i_{pump} = i_{new} \times k_3$$

where:

$$k_3 = 1 + \left(sfi \times \left[\frac{AnV}{EmV} - 1 \right] \right)$$

where sfi is a scale factor.

22. The method of claim 20, further comprising reducing an instantaneous pump pulse ON time OT_{pump} from an initial value OT_{SP} in accordance with:

$$OT_{pump} = OT_{SP} \times k_4$$

where:

$$k_4 = 1 + \left(sfo \times \left[\frac{AnV}{EmV} - 1 \right] \right)$$

where sfo is a scale factor.

23. The method of claim 20 further comprising reducing an instantaneous pump pulse RELAXATION time from an initial value RT_{SP} in accordance with:

$$RT_{pump} = RT_{SP} \times k_5$$

where:

$$k_5 = 1 + \left(sfr \times \left[\frac{AnV}{EmV} - 1 \right] \right)$$

where sfr is a scale factor.

24. The method of claim 12 wherein the looped steps of the method repeat until AnV is less than the Null Window or the elapsed time value exceeds t_3.

25. A method for pumping a sealed internal reference chamber of a solid electrolyte oxygen sensor, having an internal electrode and an external electrode, during a dynamically controlled, null balancing, initialization process, said method comprising:

a. initializing a set of pumping current pulse parameters controlling pulse ON time, post pulse RELAXATION time and pulse magnitude;

b. applying a pulsed pumping current based on said set of pulse parameters to the internal and external electrodes, wherein the application of current transitions the chamber from a substantially evacuated state to a substantially null or

balanced oxygen partial pressure state with respect to an applied external unknown gaseous environment;

c. periodically comparing the Nernst voltage of the sensor to a predetermined limit to determine whether the chamber is at a null or balanced state;

d. comparing an elapsed time from the application of said pulsed pumping current to a third predetermined time limit to determine if the sensor has failed, and

e. progressively reducing at least one of the magnitude, ON time and RELAXATION time of said pumping current pulses to slow the transition as the chamber approaches the null or balanced oxygen partial pressure state.

26. The method of claim 25 further comprising initializing a pump current pulse ON time control variable OT_{pump} to a first maximum preprogrammed value OT_{SP}.

27. The method of claim 25 further comprising initializing a pump current pulse RELAXATION time control variable RT_{pump} to a first maximum preprogrammed value RT_{SP}.

28. The method of claim 25 further comprising initializing a pump magnitude control variable i_{pump} to a first maximum value i_{FS}.

29. The method of claim 25 wherein the method further comprises a sensor nulling loop comprising:

measuring the Nernst voltage across the electrodes;

based on said voltage, determining whether the sensor is at the null state;

if the sensor is not at the null state, determining whether an elapsed time during the nulling loop exceeds a third preprogrammed time limit, and

if the elapsed time does not exceed the time limit, dynamically reducing the pumping current pulse parameters and repeating the nulling loop, and

modifying a pumping current applied to the sensor electrodes.

30. The method of claim 29 wherein the measurement of the condition of the sensor in a first iteration of said nulling loop applies a pump pulse and relaxation interval to said sensor to establish a first oxygen partial pressure aPP_{REF} in the chamber.

31. The method of claim 29 wherein the sensor null state determination further comprises comparing a sensor absolute Nernst voltage value AnV to a preprogrammed target value Null Window such that a value of AnV less than the Null Window value indicates the sensor is at the null or balanced state.

32. The method of claim 29, wherein the elapsed time limit determination further comprises:

comparing the measured elapsed time from a first application of the pumping current in a first iteration of said nulling loop to the preprogrammed time limit value t_3, and

determining the sensor to have failed if the elapsed time is greater than t_3.

33. The method of claim 29 further comprising a dynamic reduction process that comprises:

comparing a sensor Nernst voltage absolute value AnV to a preprogrammed trip value mVTrip, such that an AnV value less than mVTrip triggers a set of pump pulse dynamic reduction expressions in an alternate sensor nulling loop and

an AnV value greater than mVTrip triggers repetition of the sensor nulling loop using the first initialized pump pulse ON time and RELAXATION time parameters.

34. The method of claim 29 further comprising a sensor pumping current magnitude modification step, which adjusts a currently applied pumping current value i_{pump} in accordance with:

$$i_{pump} = i_{FS} \times k_6$$

where:

$$k_6 = \left(\frac{aPP_{REF}}{sPP_{AIR}} \right)^{\left(\frac{1}{sfp}\right)}$$

where aPP_{REF} represents an oxygen partial pressure of the sensor sealed internal reference chamber, sPP_{AIR} represents an oxygen partial pressure of air at a standard barometric pressure value, and where an output result of the expression k_6 is maximally limited to a value of 1 in a case where aPP_{REF} is greater than sPP_{AIR}..

35. The method of claim 33 wherein the alternate sensor nulling loop further comprises:

a pump pulse magnitude modification expression, a pump pulse ON time reduction expression and a pump pulse RELAXATION time reduction expression.

36. The method of claim 35 further comprising modifying an instantaneous pump pulse current magnitude variable i_{pump} from a first maximum value i_{FS} to a next value according to:

$$i_{pump} = i_{FS} \times k_3 \times k_6$$

where:

$$k_3 = 1 + \left(sfi \times \left[\frac{AnV}{EmV} - 1 \right] \right)$$

where sfi is a scale factor;

and:

$$k_6 = \left(\frac{aPP_{REF}}{sPP_{AIR}} \right)^{\left(\frac{1}{sfp} \right)}$$

where aPP_{REF} represents an oxygen partial pressure of the sensor sealed internal reference chamber, sPP_{AIR} represents an oxygen partial pressure of air at a standard barometric pressure value and where an output result of the expression k_6 is maximally limited to a value of 1 in a case where the value of aPP_{REF} is greater than a value of sPP_{AIR}.

37. The method of claim 35 further comprising reducing an instantaneous pump pulse ON time OT_{pump} from an initial value OT_{SP}, in accordance with:

$$OT_{pump} = OT_{SP} \times k_4$$

where:

$$k_4 = 1 + \left(sfo \times \left[\frac{AnV}{EmV} - 1 \right] \right)$$

where sfo is a scale factor.

38. The method of claim 35 further comprising reducing an instantaneous pump pulse RELAXATION time RT_{pump} from an initial value RT_{SP} according to:

$$RT_{pump} = RT_{SP} \times k_5$$

where:

$$k_5 = 1 + \left(sfr \times \left[\frac{AnV}{EmV} - 1 \right] \right)$$

where sfr is a scale factor.

39. The method of claim 25 wherein the looped steps of the method repeat until AnV is less than the Null Window or the elapsed time value exceeds t_3.

40. A method for pumping a sealed internal reference chamber of a solid electrolyte oxygen sensor, having an internal electrode and an external electrode, during a dynamically controlled, renull tracking or rebalancing process, said method comprising:

a. initializing a set of pumping current pulse parameters controlling pulse ON time, post pulse RELAXATION time and pulse magnitude;

b. applying a pulsed pumping current based on said set of pulse parameters to the internal and external electrodes, wherein the application of current transitions the chamber from an unbalanced state to a substantially null or balanced state with respect to an applied external unknown gaseous environment;

c. periodically comparing the Nernst voltage of the sensor to a predetermined limit to determine whether the chamber is at the null or balanced state, and

d. progressively reducing at least one of the magnitude, ON time and RELAXATION time of said pumping current pulses to slow the transition as the chamber approaches the null or balanced oxygen partial pressure state.

41. The method of claim 40 further comprising initializing a pump current pulse ON time control variable OT_{pump} to a first maximum preprogrammed value OT_{SP}.

42. The method of claim 40 further comprising initializing a pump current pulse RELAXATION time control variable RT_{pump} to a first maximum preprogrammed value RT_{SP}.

43. The method of claim 40 wherein the method further comprises a sensor nulling loop comprising:

modifying a pumping current applied to the sensor electrodes;

measuring the Nernst voltage across the electrodes;

based on said voltage, determining whether the sensor is at the null state;

if the sensor is not at the null state, dynamically reducing the pumping current pulse parameters and repeating the nulling loop.

44. The method of claim 43 further comprising a sensor pumping current magnitude modification step, which adjusts a currently applied pumping current value i_{pump} in accordance with:

$$i_{pump} = i_{FS} \times k_6$$

where:

$$k_6 = \left(\frac{aPP_{REF}}{sPP_{AIR}} \right)^{\left(\frac{1}{sfp}\right)}$$

where aPP_{REF} represents an oxygen partial pressure of the sensor sealed internal reference chamber, sPP_{AIR} represents an oxygen partial pressure of air at a standard barometric pressure value and where an output of the expression k_6 is maximally limited to a value of 1 in a case where aPP_{REF} is greater than sPP_{AIR}.

45. The method of claim 43 wherein the sensor null state determination further comprises comparing a sensor absolute Nernst voltage value AnV to a preprogrammed target value Null Window such that a value of AnV less than the Null Window value indicates the sensor is at the null or balanced state.

46. The method of claim 43 further comprising a dynamic reduction process that comprises:

comparing a sensor Nernst voltage absolute value AnV to a preprogrammed trip value mVTrip, such that an AnV value less than mVTrip triggers a set of pump pulse dynamic reduction expressions in an alternate sensor nulling loop, and

an AnV value greater than mVTrip triggers repetition of the sensor nulling loop with the first initialized pump pulse ON time and RELAXATION time parameters.

47. The method of claim 46, wherein the alternate sensor nulling loop further comprises: a pump pulse magnitude modification expression, a pump pulse ON time reduction expression and a pump pulse RELAXATION time reduction expression.

48. The method of claim 47, further comprising modifying an instantaneous pump pulse current magnitude variable i_{pump} from a first maximum value i_{FS} to a next value according to:

$$i_{pump} = i_{FS} \times k_3 \times k_6$$

where:

$$k_3 = 1 + \left(sfi \times \left[\frac{AnV}{EmV} - 1 \right] \right)$$

where sfi is a scale factor and:

$$k_6 = \left(\frac{aPP_{REF}}{sPP_{AIR}} \right)^{\left(\frac{1}{sfp}\right)}$$

where aPP_{REF} represents an oxygen partial pressure of the sensor sealed internal reference chamber, sPP_{AIR} represents an oxygen partial pressure of air at a standard barometric pressure value and where an output result of the expression k_6 is maximally limited to a value of 1 in a case where aPP_{REF} is greater than sPP_{AIR}.

49. The method of claim 47 further comprising reducing an instantaneous pump pulse ON time OT_{pump} from an initial value OT_{SP} according to:

$$OT_{pump} = OT_{SP} \times k_4$$

where:

$$k_4 = 1 + \left(sfo \times \left[\frac{AnV}{EmV} - 1 \right] \right)$$

where sfo is a scale factor sfo.

50. The method of claim 47 further comprising reducing an instantaneous pump pulse RELAXATION time RT_{pump} from an initial value RT_{SP} according to:

$$RT_{pump} = RT_{SP} \times k_5$$

where:

$$k_5 = 1 + \left(sfr \times \left[\frac{AnV}{EmV} - 1 \right] \right)$$

where sfr is a scale factor.

51. The method of claim 40 wherein the looped steps of the method repeat until AnV is less than the Null Window.